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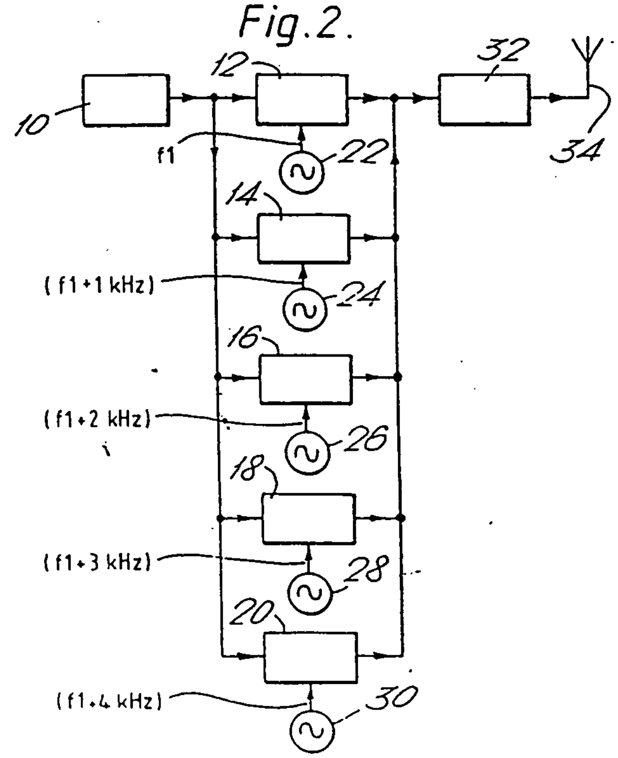
(58) Field of search
H4P
H4L

(54) Transcription of digital data

(57) The transmission of digital data over a data link, particularly an H.F. radio link, can be corrupted by narrow-band, high level interference signals randomly distributed in frequency.

The uncorrupted transmission of data can be made more possible by a frequency diversity digital data transmission system in which a signal channel is divided into a plurality of lesser bandwidth sub-channels, each of which is modulated across substantially its entire bandwidth by a multi-level, spectrally efficient modulation scheme, for example 8PSK, 16QAM, 64QAM. In a receiver the sub-channels are examined for narrow-band interference and the data signal is demodulated using a decision algorithm based on the sub-channel outputs, and an assessment of sub-channel reliability.

Fig.2.



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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

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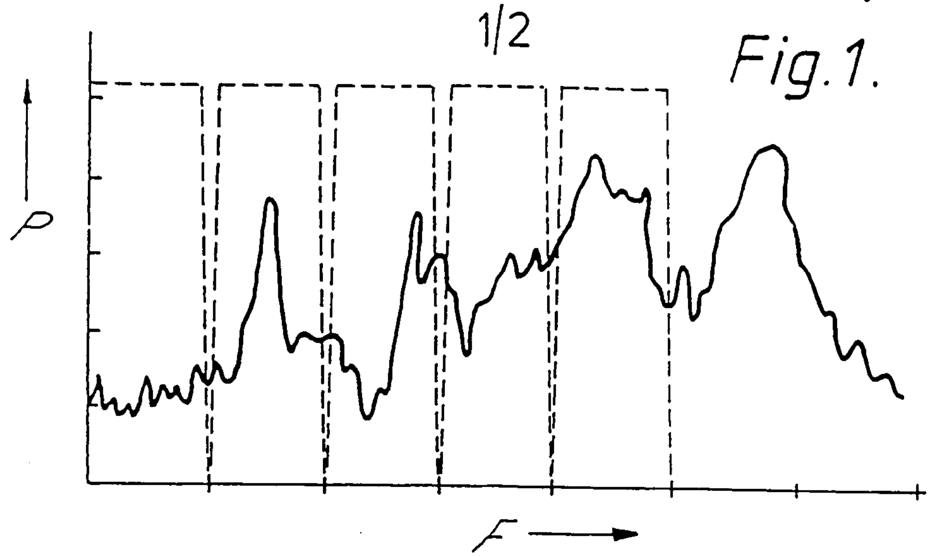
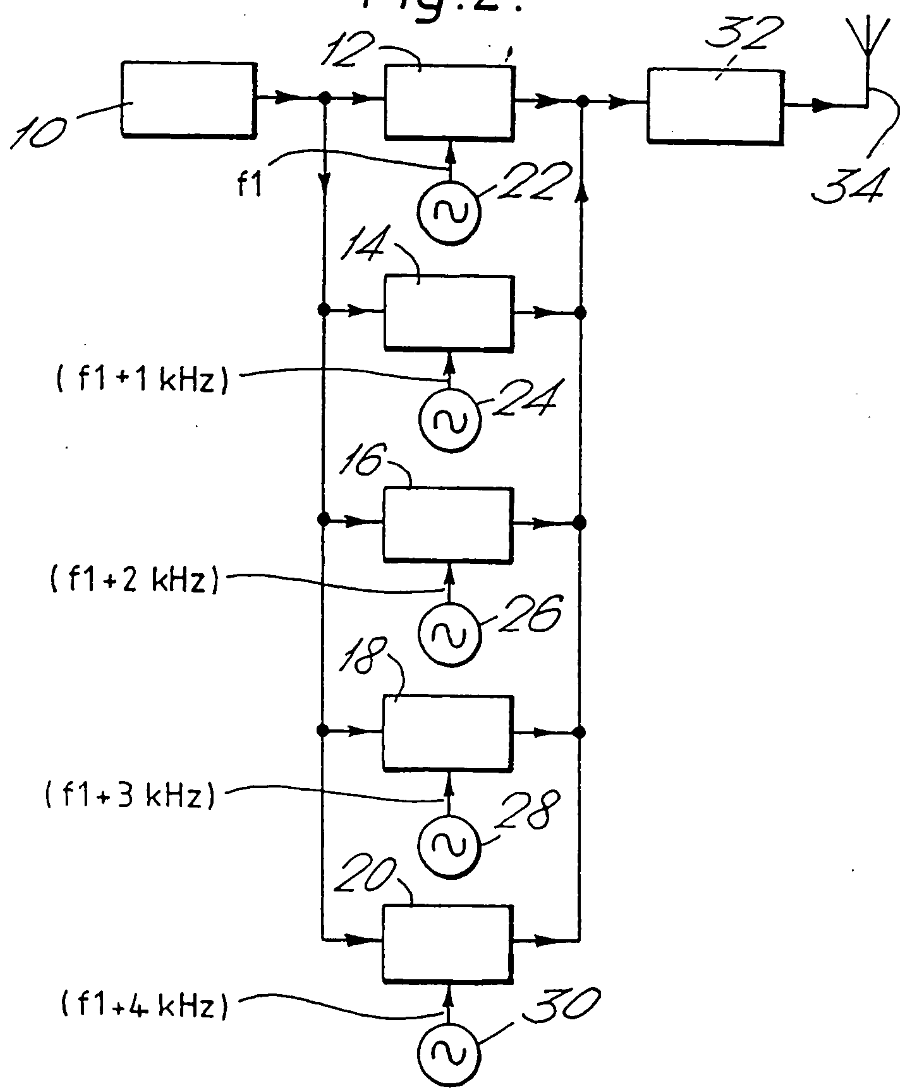


Fig.1.

Fig.2.



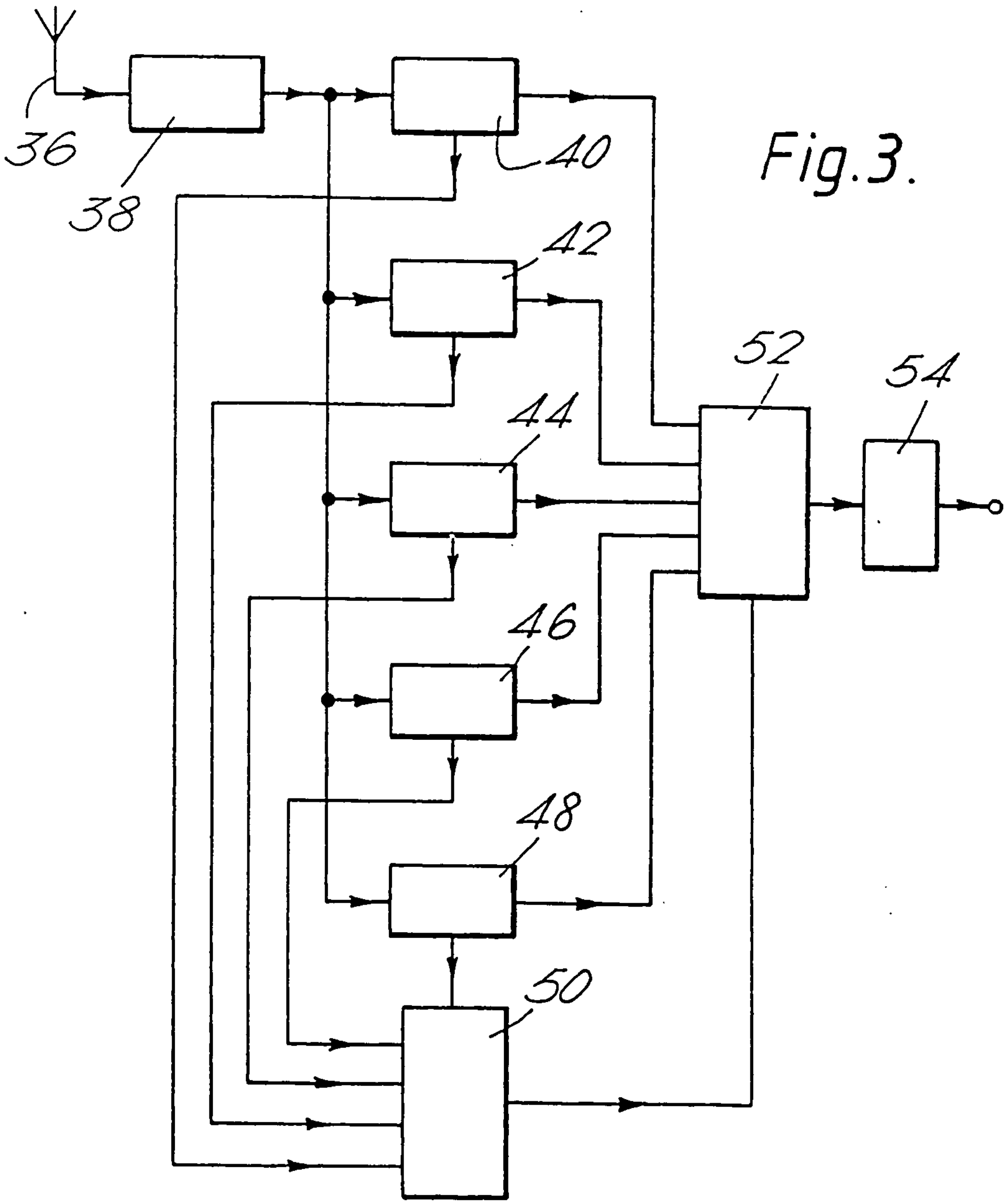


Fig.3.

SPECIFICATION

Transmission of digital data

The present invention relates to the transmission of digital data in the presence of narrow-band interference.

A problem when transmitting digital information over a data link, which may be an H.F. radio link, is that the information becomes corrupted in transmission by narrow-band, high level interference signals randomly distributed in frequency. Known systems for combating such interference involve reducing the data rate in a given bandwidth or, conversely, increasing the bandwidth for the same data rate.

An object of the present invention is to reduce the effects of narrow-band interference when transmitting digital information at a high data rate over a data link of a predetermined bandwidth.

According to the present invention there is provided a digital data transmission system in which a transmission channel of defined bandwidth is divided into a plurality of lesser bandwidth sub-channels, digital data informatin to be transmitted is modulated over substantially the entire bandwidth of each of the said sub-channels using a multi-level modulation scheme and at the receiver the digital data is recovered from at least one of the sub-channels.

By using a combination of frequency diversity and a spectrally efficient, multi-level modulation sheme, the chance of at least one of the frequency diversity sub-channels being received uncorrupted is much greater than the chance of the complete channel being interference free. A further improvement can e gained by making use of all the received sub-channels.

Suitable multi-level modulation schemes may comprise for example, 8PSK (8 phase shift keying), 16QAM (16 quadrature amplitude modulation) or 64QAM.

At the receiver, the sub-channels are dmodulated and either steps are taken to select the best sub-channel at any instance or the data is recovered by making a decision using all the sub-channel outputs.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a graph of an example of H.F. interference, and

Figures 2 and *3* are block schematic circuit diagrams of a transmitter and a receiver, respectively, suitable for use with the data transmission system in accordance with the present invention.

Referring to Figure 1, there is shown a graph of power P in 10dB per division against frequency F in 1kHz per division and illustrates typical H.F. interference. Part of the interference consists of a background of noise-like signals, but another part, the large amplitude peaks in Figure 1, consists of narrow-band interference. In many cases the narrow-band interference is the dominant cause of errors at the output of the receiver.

Thus, taking as an example a transmission channel of 5.0kHz occupied by a signal with a data rate of 2.4k bits/sec., if the channel is badly corrupted by narrow-band interference then the entire signal is unusable. Since as is shown in Figure 1 the narrow-band noise is not distributed uniformly across the frequency band, then adopting frequency diversity using several, for example 5, sub-channels within an overall channel it is likely that at any instant in time at least one of the sub-channels is free from narrow-band interference and the data is received uncorrupted. Because all the message information is transmitted in each sub-channel, then the transmitted data can be recovered even if one or more sub-channels are unusable. This frequency diversity can be achieved without reduction in data rate if a spectrally efficient multi-level modulation scheme is used so that each sub-channel of for example 1kHz bandwidth is sending data at 2.4k bits/sec. Such multi-level modulation schemes may comprise, for exmple, 8PSK, 16QAM or 64QAM. At a receiver all the sub-channels are received and demodulated and either digital data is recovered from one of the sub-channels, that is the one having least interference, or the data value is recovered by making a decision vased on all the sub-channel outputs.

For example, considering single data bits, the following algorithm could be used to obtain the recovered data value (D):-

$$D=1 \text{ if } \Sigma\, w_iD_i/\Sigma w_i \geq 0.5$$
$$D=0 \text{ if } \Sigma\, w_iD_i/\Sigma w_i < 0.5$$

where D_i is the output of the $_i$-th sub-chanel and w_i is the a weighting factor applied to the i-th sub-channel output. The decision alogorithm can take various forms. For example, if the weights are all unity then it is equivlent to majority decision decoding. If all the weights are zero except one then this amounts to selection of a single sub-channel. If the weights are chosen according to the estimated reliability of the associated sub-channels then this is a weighted combining scheme. The reliability of each sub-channel could be determined, for example, by the signal-to-noise ratio in that sub-channel. The data reliability can be estimated either on a bit by bit basis or using a short term average. A new set of weights could be determined for each received bit, or alternatively, less frequently.

Figure 2 shows a transmitter system which comprises a 2.4k bits/second digital data encoder 10 which is coupled to five multi-level modulators 12, 14, 16, 18 and 20 which may comprise 8PSK, 16QAM or 64QAM modulator. The five sub-carriers f1 to (f1+4kHz) spaced one from another by 1kHz are are generated by oscillators 22, 24, 26, 28 and 30, respectively and are modulated according to the predetermined multilevel modulation scheme to form a frequency diversity signal. This signal is applied to a transmitter 32 which could be conventional single sideband (SSB) transmitter accepting a 5kHz bandwidth signal. The transmitter output is applied to an antenna 34.

The reciever system shown in Figure 3 comprises a receiver 38 which could be a conventional SSB receiver which is connected to an antenna 36 and has an output bandwidth of 5kHz. Each of the

sub-channels of the frequency diversity signal is applied to a respective demodulator 40, 42, 44, 46 and 48 which has its own sub-carrier frequency generator. The detected signals from the demodulators 40 to 48 are applied to a decision unit 52 which makes a decision based on a decision algorithm as to the correct output data value, based on the sub-channel outputs and the assessment of sub-channel reliability made by a reliability measurement unit 50. The decision making process will usually be continuous because the occurrence of narrow-band interference cannot be predicted. The output of the decision unit 52 is supplied to a data decoder 54.

Various ways may be used for determining the degree to which each of the sub-channels is corrupted by H.F. narrow-band interference. For example, a comparison can be made between the amplitude of the signal in each of the respective sub-channels and the mean amplitude for all the sub-channels. It is then reasonable to assume that any sub-channel with an amplitude much larger than the mean is corrupted by interference. The phase jitter on each of the sub-carriers could also be used as an indication of interference. Another method would be for the encoder 10 to insert error detection or correction coding into the encoded signal and for this coding to be used in the receiver to determine which sub-channels are corrupted by interference.

The digital information bits applied to each of the modulators 12 to 20 in Figure 2 need not necessarily be transmitted on all the sub-channels simultaneously. For example, the sub-channel signals could each be delayed in time by a different amount resulting in both time and frequency diversity. However, the complete message would still be transmitted down each sub-channel. At the receiver corresponding time delays would be required after demodulation to enable correct combining of the sub-channel signals.

Not shown in Figure 3, the sub-channel signal combination with appropriate weighting factors could be carried out before demodulation. In this case the sub-carriers should be phase locked to each other. This phase locking would also be desirable in minimising the peak-to-mean power ratio of the transmitted signal.

Although not shown, instead of using a single receiver one could use five separate receivers each one assigned to a different channel.

The modems 12 to 20 and 40 to 48 may be serial modems with or without adaptive equalisers or parallel modems, although the latter are more complicated technically and have a peak power limitation.

The transmission system in accordance with the present invention is particularly applicable to groundwave communication over distances of up to about 150 km, but could be used over longer ranges with adaptive equalisation.

CLAIMS

1. A digital data transmission system in which a transmission channel of defined bandwidth is divided into a plurality of lesser bandwidth sub-channels, digital data information to be transmitted is modulated over substantially the entire bandwidth of each of the said sub-channels using a multi-level modulation scheme and at the receiver the digital data is recovered from at least one of the sub-channels.

2. A transmission system as claimed in Claim 1, wherein the receiver includes means for examining each of the sub-channels and for selecting a sub-channel having the minimum of narrow-band noise for further processing.

3. A transmission system as claimed in Claim 2, wherein in encoding the digital data an error detection code is applied and in the receiver, said means detects the number of errors in each sub-channel signal.

4. A transmission system as claimed in Claim 2, wherein said means compares the digital data signals in each of said sub-channels and a majority voting system is used to recover the transmitted data.

5. A transmission system as claimed in Claim 2, wherein said means compares the amplitude of the signal in each sub-channel with an expected amplitude and determines which sub-channel(s) at any one time is (or are) deemed to be interference free.

6. A transmission system as claimed in claim 1, wherein the receiver includes means for combining the signals on the respective sub-channels and providing an output digital signal for further processing.

7. A transmission system as claimed in Claim 6, wherein the receiver includes means for estimating the reliability of each of the sub-channel data signals and using this information in an algorithm to combine the sub-channel signals.

8. A transmission system as claimed in any one of Claims 1 to 7, wherein the multi-level modulation scheme is 16QAM (quadrature amplitude modulation).

9. A transmission system as claimed in any one of Claims 1 to 7, wherein the multi-level modulation scheme is 64QAM

10. A transmission system as claimed in any one of Claims 1 to 7, wherein the multi-level modulation scheme is 8PSK (phase shift keying).

11. A transmission system as claimed in any one of Claims 1 to 10, wherein the digital signals used to modulate each of the sub-carriers are delayed in time by different amounts.

12. A digital data transmission system substantially as hereinbefore described with reference to the accompanying drawings.

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